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# Severe traumatic brain injury in Switzerland – feasibility and first results of a cohort study

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## Abstract

*Background:* We aimed to study the incidence and outcome of severe traumatic brain injury (TBI) in Switzerland and to test the feasibility of a large cohort study with case identification in the first 24 hours and 6-month follow-up.

*Methods:* From January to June 2005, we consecutively enrolled and followed up all persons with severe TBI (Abbreviated Injury Score of the head region >3 and Glasgow Coma Scale <9) in the catchment areas of 3 Swiss medical centres with neurosurgical facilities. The primary outcome was the Extended Glasgow Outcome Scale (GOSE) after 6 months. Secondary outcomes included survival, Functional Independence Measure (FIM), and health-related quality of life (SF-12) at defined time-points up to 6 months after injury.

*Results:* We recruited 101 participants from a source population of about 2.47 million (ie, about 33% of Swiss population). The incidence of severe TBI was 8.2 per 100,000 person-years. The overall case fatality was 70%: 41 of 101 persons (41%) died at the scene of the accident. 23 of 60 hospitalised participants (38%) died within 48 hours, and 31 (53%) within 6 months. In all hospitalised patients, the median GOSE was 1 (range 1–8) after 6 months, and was 6 (2–8) in 6-month survivors. The median total FIM score was 125 (range 18–126); median-SF-12 component measures were 44 (25–55) for the physical scale and 52 (32–65) for the mental scale.

*Conclusions:* Severe TBI was associated with high case fatality and considerable morbidity in survivors. We demonstrated the feasibility of a multicentre cohort study in Switzerland with the aim of identifying modifiable determinants of outcome and improving current trauma care.

*Key words: cohort study; traumatic brain injury; case fatality; morbidity; functional outcome; health-related quality-of-life*

## Introduction

Severe traumatic brain injury (TBI) is a major burden for societies in both the developed and developing world [1, 2]. It is often disabling in young patients and causes substantial direct and indirect costs [1]. Whether care for TBI patients has improved in recent years is an on-going issue [3, 4].

The incidence of severe TBI was 17 per 100,000 person-years in a population-based study in France, with severe TBI defined as an Abbreviated Injury Scale score of head region ($AIS_{Head}$) of 4 or 5 [5]. The incidence was 9 per 100,000 person-years in Germany, when severe TBI was defined as a Glasgow Coma Score (GCS) <9 [6]. Reliable data on the incidence and outcome of TBI are important in the planning of out-of-hospital emergency medical services (OHEMS) and acute care and rehabilitation centres. Nevertheless, comprehensive data on severe TBI are currently not available in Switzerland, but we know that regional trauma systems reduce mortality [7, 8].

In population-based studies on severe TBI, the case fatality ranged from 30% in France [5] (including hospitalised patients only) to 47% and

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more than 60% in Germany (including pre-hospital deaths) [6, 9]. One cohort study estimated functional outcome using the Glasgow Outcome Scale (GOS) at hospital discharge, but not beyond this time-point: 70% of patients with $AIS_{Head}$ of 4 and 23% of those with $AIS_{Head}$ of 5 recovered well [5]. If severe TBI was defined as GCS <9 in the same population, only 18% recovered well [10]. Health-related quality of life (HRQOL) has been studied in only few patients with severe TBI [11, 12]. Lack of information on long-term functional status and HRQOL after TBI impairs the planning of the health services involved, and may result in suboptimal medical care for TBI patients.

We report on the initial phase of a population-based cohort study on "Patient-relevant Endpoints after Brain Injury from Traumatic Accidents" (PEBITA) conducted at three medical centres. The aim is to estimate the incidence and outcome of severe TBI in Switzerland, and to identify potential outcome determinants. These initial findings comprise the feasibility of case identification, data collection and management, and follow-up of patients.

## Material and methods

### Study design

We conducted a prospective cohort study and collected data on patient demography, pre-hospital and in-hospital management and treatment, and long-term outcome. In the initial phase, the three trauma centres in Zürich, Lausanne and St. Gallen participated after approval by their local ethics committees. The neurosurgical facilities of all three centres are the exclusive providers of care for patients with severe TBI in the respective catchment area. Written informed consent by proxy within 14 days after injury replaced consent by patients, who were all severely injured at the time of enrolment.

### Case identification and eligibility criteria

From 1st January to 30th June 2005, we enrolled patients with 1) severe TBI from blunt and penetrating trauma (see criteria below), and 2) admission to one of the three participating trauma centres. Patients were considered potentially eligible if head trauma and unconsciousness were reported by OHEMS. Every day, a local study collaborator in each participating hospital asked the physicians in charge of neurosurgical emergencies regarding eligible patients admitted within the last 24 hours. The departments of legal medicine were questioned weekly about potentially eligible trauma victims. We defined the source population in the catchment areas based on 2004 population statistics and the following approximation of geographical areas: for Zurich, the canton of Zurich (excluding the Winterthur region), cantons of Glarus and Schaffhausen, and 50% of the canton of Thurgau (total 1.14 million inhabitants); for Lausanne, canton of Vaud (total 0.65 million inhabitants); for St. Gallen, cantons of St. Gallen, Appenzell Innerrhoden and Ausserrhoden, 50% of the canton of Thurgau, and the Principality of Liechtenstein (total 0.68 million inhabitants). The total source population was 2.47 million inhabitants [13]. Both residents and non-residents of the catchment areas were eligible for study inclusion.

Severe TBI was defined by the presence of both criteria: $AIS_{Head}$ >3 according to in-hospital diagnosis *and* Glasgow Coma Score (GCS) <9 within first 24 hours as assessed by staff of OHEMS or admitting hospitals. For AIS assessment, we used the 1990 revision, update 1998 [14]. On the 6-point scale of AIS, values of 4 to 6 correspond to severe to fatal lesions. We included persons who died before a formal diagnosis of TBI could be made, if OHEMS and departments of legal medicine documented trauma with signs of severe head injury.

### Outcomes

The primary outcome was the Glasgow Outcome Scale Extended (GOSE) after 6 months [15]. Secondary outcomes included survival after hospital admission, potential years of life lost [16], GCS after 14 days and 3 months, hemiplegia and paraplegia after 14 days, GOSE after 3 months, functional impairment by Functional Independence Measure (FIM) after 3 and 6 months [17], and health-related quality-of-life (SF-12) after 3 and 6 months [18, 19].

### Potential outcome determinants

Potential outcome determinants included sex, age, injury mechanism (blunt or penetrating trauma; road traffic accidents; falls; other accidents; unintentional or intentional injury), severity of head injury ($AIS_{Head}$ [14], GCS, pupil reaction, diagnosis based on initial cerebral CT scan [20]), duration of coma until regaining of consciousness (GCS motor score of 6), severity of concomitant injuries (AIS in other body regions [14]) and haemoglobin level at hospital admission. Derived parameters were Simplified Acute Physiology Score (SAPS II) [21], Injury Severity Score (ISS) [22, 23], Trauma Score/Injury Severity Score (TRISS) [24]. We also recorded the length of stay in acute and rehabilitation care.

### Completeness of data

We checked the completeness of case identification in the study area and monitored the contact with the health care providers in charge, in particular in the pre-hospital setting. For each study parameter, we defined data completeness as the proportion of patients with recorded data of all patients eligible for data collection. We then calculated the median and the range of all data completeness values overall and in each of the three data collection periods of pre-hospital care, in-hospital care, and follow-up, separately. We analysed loss to follow-up and identified reasons. During the recruitment period, investigator meetings were held to share experience and ensure early identification of problems.

### Data collection and statistics

A patient dataset was adapted from the Utstein-style documentation and based on recommendations for TBI research [25, 26]. Standardised data abstraction forms were developed, explained to local study collaborators in individual interviews, and piloted. Separate forms covered the entire pathway of TBI care from the accident scene until rehabilitation. We used validated language versions in German and French of the instruments for outcome assessments. If data were ambiguous or missing, the physicians in charge were contacted for clarification.

AIS scoring was done by trained study collaborators who had access to the full medical record of study participants in the three hospitals. Data were managed and stored centrally by the Institute of Social and Preventive Medicine of the University of Bern (ISPM Bern). We used standard descriptive statistics and graphs including Kaplan-Meier curves.

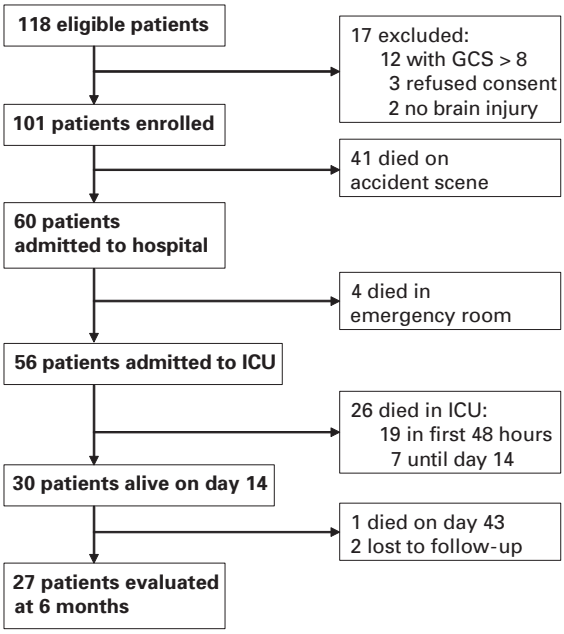
## Results

One hundred and eighteen patients were identified and considered for eligibility (figure 1). Of these, 101 patients were included (Zürich 38, Lausanne 38, St. Gallen 25). The estimated incidence was 8 per 100,000 person-years. Sixty participants were admitted to one of the three centres.

### Patient characteristics and injury mechanisms

The median age of the 101 participants was 41 years (range 2–100) (table 1). Seventy-five (74%) participants were male; their median age was 38 years (range 2–88). Twenty-six (26%) participants were female; their median age was 60 years (range 6–100). Eighty-two participants (81%) had blunt trauma. Nineteen (19%) had penetrating trauma, all of which were firearm injuries (table 1). Thirty-nine participants (40%) had road traffic accidents; their median age was 27 years (range 6–82). Thirty-one participants (31%) had sustained injuries from falls; their median age was 66 years (range 16–88 years). Other causes of injury were present in 30 participants (30%): ten of 31 from falls (32%), and 18 of 30 other injuries (60%) were intentional.

**Figure 1**
Flow chart of participants.



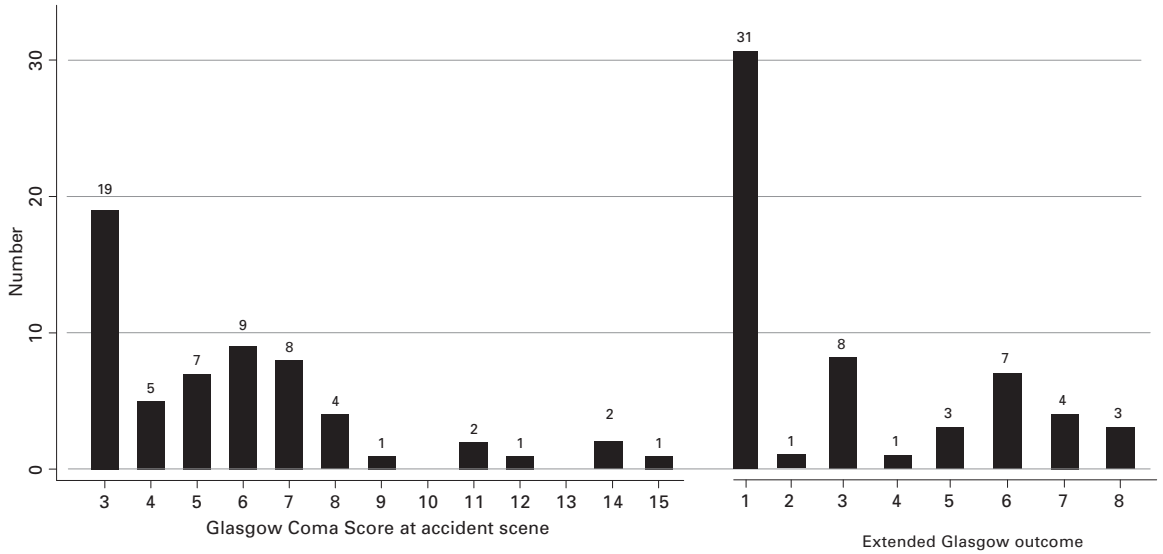

GCS = Glasgow Coma Score, ICU = Intensive Care Unit

### Severity of TBI and other injuries

The median initial GCS (ie, at the accident scene on arrival of OHEMS teams) of participants who were later hospitalised was 5 (range 3–15), and was below 9 in 52 (88%) participants (figure 2). The initial GCS was ≥9 in 7 participants (12%), and then decreased during the first 24 hours. At hospital admission, GCS was 3 in 55 of 60 hospitalised patients (92%), and in all 56 patients who left the emergency department. Most patients were sedated either before or upon arrival in the emergency department. The pupil reaction was assessed in 55 patients. It was absent unilaterally in 6 patients (11%) and bilaterally in 17 patients (31%).

$AIS_{Head}$ was 4 in 25 patients (42%), 5 in 33 (55%), and 6 in 2 patients (3%) (median $AIS_{Head}$ 5).

**Figure 2**
Neurological and functional status of hospitalised participants.



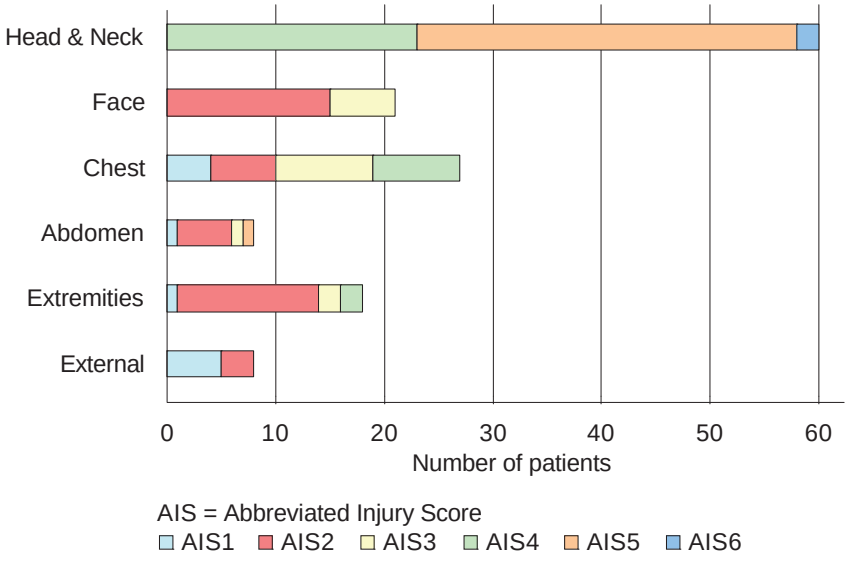

n=60; 1 missing for Glasgow Coma Score, 2 for Extended Glasgow Outcome Scale

**Table 1**
Patient characteristics and injury mechanisms.

| | Participants who died on scene | Hospitalised participants | All |
|---|---|---|---|
| **Total number** | 41 (100) | 60 (100) | 101 (100) |
| Age [years] (median, range) | 40.4 (6.4 – 99.6) | 41.1 (1.6 – 87.9) | 40.9 (1.6 – 99.6) |
| Female gender | 10 (24) | 16 (27) | 26 (26) |
| **Type of injury** | | | |
| Penetrating | 12 (29) | 7 (12) | 19 (19) |
| Blunt* | 29 (71) | 53 (88) | 82 (81) |
| *Diffuse injury I* | – | 2 (3) | – |
| *Diffuse injury II* | – | 24 (40) | – |
| *Diffuse injury III* | – | 12 (20) | – |
| *Diffuse injury IV* | – | 11 (18) | – |
| *Evacuated mass lesion* | – | 19 (32) | – |
| *Non-evacuated mass lesion* | – | 2 (3) | - |
| **Trauma mechanisms** | | | |
| Road traffic accidents: | | | |
| *All vehicles with 4 wheels* | 11 (27) | 9 (15) | 20 (20) |
| *Others* | *5 (12)* | 14 (23) | 19 (19) |
| Falls | 10 (24) | 21 (35) | 31 (31) |
| Others | 14 (34) | 16 (27) | 30 (30) |
| Unknown | 1 (2) | – | 1 (1) |
| **Intention** | | | |
| Unintentional | 20 (49) | 49 (82) | 69 (68) |
| Intentional: *Self-harm* | 19 (46) | 9 (15) | 28 (28) |
| *Violence* | 2 (5) | – | 2 (2) |
| Unclear | – | 2 (3) | 2 (2) |

* Based on initial CT scan, according to classification by Marshall et al. (reference 20). Numbers in brackets are percent if not stated otherwise.

**Figure 3**
Injury pattern of hospitalised participants.

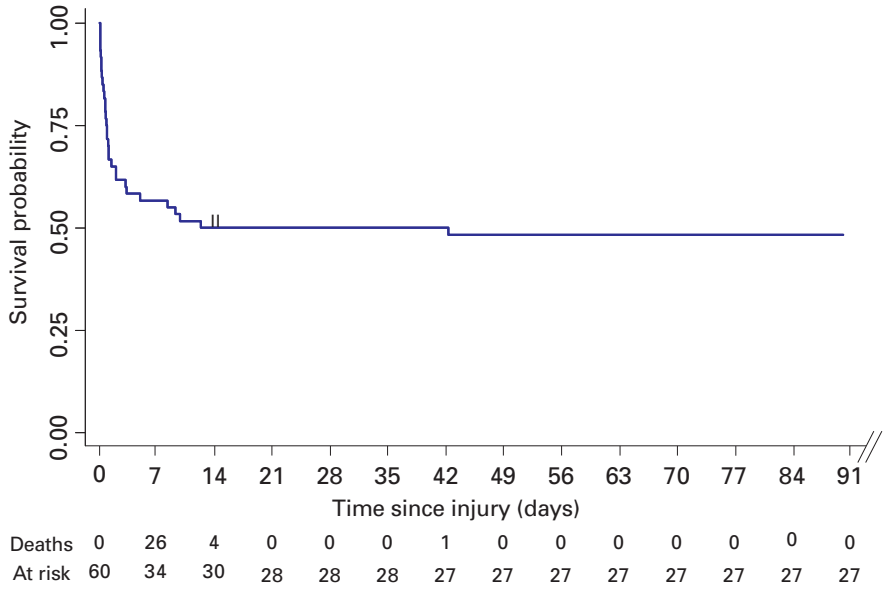



Fifty-three of 82 patients with blunt trauma were hospitalised. Of these, 49 (92%) had signs of diffuse brain injury in the initial cerebral CT scan (table 1). In 33 of these patients, cerebral oedema was present; in 11 (21%) it was unilateral and in 22 (42%) bilateral. Initial CT scans showed epidural haemorrhages in 14 (26%) patients, subdural in 35 (66%), subarachnoid in 15 (28%), and intraventricular haemorrhage in 13 (24%) patients. In 30 surviving patients, the median duration of coma was 3 days (range 0–183).

In hospitalised patients, the median ISS was 26 (range 16–75). Twenty-one patients had facial trauma (35%), 27 chest trauma (45%), 8 abdominal trauma (13%), and 18 trauma of extremities (30%) (figure 3). Overall, 40 hospitalised patients had multiple trauma; all of these had blunt cerebral trauma. SAPS II data were available for

**Figure 4**

Survial of hospitalised participants.




2 participants are censored at day 14 (II); graph truncated at day 91

48 patients: the median was 51 (range 21–150). The blood haemoglobin concentration on arrival in hospital was measured in 54 patients; the median was 124 g/L (range 44–173). It was below 80 g/L in 4 patients (7%), ie, compatible with active bleeding.

## Outcomes

Of 60 hospitalised patients, 23 died within 2 days including all seven patients with penetrating trauma (figure 4). Thirty patients died within 14 days; one patient died after 43 days of pneumonia (figure 4). The overall in-hospital case fatality was 52% (31 of 60 patients); in patients with blunt trauma it was 45% (24 of 53 patients). Two patients were lost to follow-up; one returned overseas after recovery, and another did not respond when contacted. The most likely cause of death in 27 of 31 (87%) hospitalised patients with fatal outcome was brain injury. In 50 participants, TRISS could be calculated: the median was 66% (range 0.3–96). In these patients, the actual observed 30-day survival was 52%, ie, 26 patients. Based on TRISS data, the expected number of survivors was 28. Overall, the 71 trauma victims who died either before or after hospital admission lost a median of 26 potential life years until age 70, and a total of 1744 years. Men lost 1511 (87%) life years and women 233 (13%). 19 of 71 (27%) trauma victims died due to penetrating trauma from firearms.

After 14 days, the median GCS in 30 participants was 12 (range 3–15). Of these, 20 (66%) were not sedated, and the median GCS was 14 (range 7–15). Median $GCS_{Eyes}$ was 4 (range 1–4), $GCS_{Verbal}$ 4 (range 1–5), and $GCS_{Motor}$ 6 (range 5–6). Seven (23%) participants had a severe unilateral loss of motor function. Five of 28 participants with available data (18%) had a severe unilateral loss of sensory function. None had tetraplegia or paraplegia.

After 3 months, 20 of 24 participants had regained a GCS of 15. At this time, the functional outcome was favourable (GOSE >4) in 24 of 58 hospitalised patients with available data (41%). The total FIM score was available for 24 patients; the median was 119 (range 18–126). The median FIM motor score was 88 (range 13–91). The median cognitive score was 30 (range 5–35).

After 6 months, the median GOSE for all 58 patients was 1 (range 1–8) (figure 2). In the 27 participants who survived until 6 months, the median GOSE was 6 (range 2–8). In 17 of 58 patients (29%), the outcome was favourable, and in 10 (17%) unfavourable (GOSE ≤4). After 6 months, the total FIM score was available for 26 patients: the median was 125 (range 18–126). The median FIM motor score at that time was 91 (range 13–91), and the cognitive score was 34 (range 5–35). In 6 patients (23%), functional independence was still impaired with total FIM score below 100. Eighteen of 27 patients (67%) were at home, 3 in assisted living facilities, and 6 in rehabilitation centres. Six of 27 patients (22%) had regained work capacity in their previous profession fully, and 9 (33%) partially. Twelve patients (45%) worked in a protected environment or did not work. Of 22 participants, we obtained information on HRQOL (SF-12) after 6 months. The mean physical component measure was 44 (median 46; range 25–55). The mean mental component measure was 52 (median 55; range 32–65).

## Characteristics of in-hospital care

The median delay from emergency call to surgical intervention was 3 hours (range 2–9). Twenty-one patients had intracranial mass lesions of which 19 required surgery with evacuation (table 1). In 7 of these (37%), surgery started more than 3 hours after the accident. Nine patients had decompressive craniectomy within 24 hours. The intracranial pressure was moni-

tored in 24 of 60 hospitalised patients (40%). In the 30 survivors, the median length of stay in intensive care was 7 days (range 1–49), and in acute care (including ICU) 20 days (range 5–68). After discharge from acute care, 25 patients had specialised neuro-rehabilitation in 13 different rehabilitation centres. The median stay of 23 patients in neuro-rehabilitation was 59 days (range 4–164).

### Study feasibility

Most patients hospitalised with severe TBI were identified early on without any difficulties. One child was not identified within 24 hours because contact with the paediatric acute care hospital could not be established in time. Trauma victims who died on the accident scene could be identified at two centres by both OHEMS and departments of legal medicine. One department of legal medicine refused collaboration, and consequently identification of fatal cases was only by OHEMS. The median data completeness of all study variables was 85% (range 43–100%); the median data completeness was 63% (range 53–73%) in the pre-hospital period, 100% (range 75–100%) for the in-hospital period, and 89% (81–100%) during follow-up, respectively.

## Discussion

Over a 6-month period, we identified 101 patients with blunt or penetrating severe TBI in a source population of about 2.47 million. The estimated incidence of severe TBI was 8 per 100,000 person-years, with a case fatality of 70%. Men lost more potential life years than women as they were younger at the time of the accident. In survivors, the functional outcome after 6 months was moderate with a median GOSE of 6. The identification of participants early on was nearly complete; only two were lost to follow-up.

### Limitations and strengths

We collected data from a variety of sources including OHEMS reports, hospital charts, radiology reports, and self-reported information from patients and proxies. We strived to achieve sufficient data quality using a standardised dataset. The data collection was more complete during the in-hospital period than before hospital admission.

We realised that, particularly in the pre-hospital setting, not all relevant data are noted on OHEMS protocols and are therefore not available when requested later. Insufficient documentation of medical interventions may have legal implications, and we hope that this report will contribute to improving this. In particular, OHEMS report forms should be standardised and their use monitored routinely in all Swiss regions.

Another limitation of our study is related to the assessment instruments used for patient interviews. Such data are prone to information bias. Many TBI patients have memory problems, their ability to concentrate on a questionnaire is limited, and overestimation of their own situation is common. We considered such potential pitfalls when planning the study, but cannot exclude influence on our data from such factors.

The sample size in this initial study phase was limited and this precluded more advanced analyses. We were nevertheless able to collect valid study data along the entire TBI care chain, from the accident scene until rehabilitation. This enabled us to document a care profile for severe TBI in Switzerland and to generate relevant research questions to be tested in larger datasets.

The catchment areas of the three participating hospitals represent different parts of the Swiss population, for instance with regard to urban versus rural settings or to language regions. However, we do not know whether our findings can be generalised to the whole country or settings abroad. Also, our estimate for TBI incidence has to be interpreted with caution since it is influenced by the definition of these catchment areas which determine the population denominator.

In many previous TBI studies, follow-up ended with hospital discharge or analyses were based on registry data. Our follow-up period was sufficiently long to investigate endpoints that matter to patients, such as quality of life and return to work. Our methods proved to be useful to obtain data on potential outcome determinants in the pre-hospital, in-hospital and rehabilitation setting. However, response during follow-up may be influenced by factors such as clinical course and quality of life, and our estimates may be overestimated for these reasons. We achieved good case identification at three centres, and lost only two patients to follow-up. Identification of the reasons for missing data in the pre-hospital setting has enabled us to optimise our data collection methods.

### Key results in context with other studies

The incidence of severe TBI was lower than previous estimates [5, 6]. Compared with these, our inclusion criteria were more specific because we used both GCS and $AIS_{Head}$. In a French study, 93% of patients with $AIS_{Head}$ 4 and 39% of those with $AIS_{Head}$ 5 had an initial GCS of ≥9 [5]. These patients would not have been included in our study. The in-hospital case fatality was 52%. In a European survey, it was 40% (ie, 192 of 481 patients with GCS <9 during pre-hospital or acute

phase) [27]. Higher case fatality is found with penetrating and with intentional injury [28, 29]. In our study, penetrating TBI was more frequent than in the European survey [5]. Also, many hospitalised TBI patients died during the first two days after the accident. If a true difference in case fatality of about 12% between study populations was confirmed, even after adjustment for case-mix, this would deserve further research on pre-hospital and early in-hospital trauma care.

The outcome after 6 months was less favourable than in the European survey [27]. The use of different score versions (ie, original GOS [27] versus GOSE in our study) or random variation are possible explanations. Most survivors had regained general functional independence and half of them worked full- or part-time. FIM scores after 6 months compare favourably to two US cohort studies with mean total FIM scores of 112 and 115 after one year [30, 31]. However, they contrast with outcome assessed by GOSE, which was only moderate. Surprisingly, physical quality of life (SF-12) was only slightly lower than the norm for healthy Europeans, with mean scores ranging from 49.4 to 51.2, and the Swiss norm of 49.8 [19, 32]. On the mental scale, our estimate even exceeded these norms (European countries 47.8 to 52.9, and Switzerland 46.3). Participants with better quality of life may have been more likely to provide such data. Furthermore, TBI patients are known to overestimate their situation [33].

GCS is routinely used to assess the neurological state of TBI patients, despite known shortcomings, in particular in the pre-hospital setting [34]. GCS at hospital admission has previously been used as an outcome predictor [35]. However, in our study almost all patients were sedated and intubated before arrival at the emergency unit, which makes reliable GCS scoring difficult, if not impossible. If all three GCS domains are to be assessed, the time-point for the most valid assessment may be at the accident scene, ie, before medical interventions take place. Alternatively, it has been suggested to restrict rapid initial neurological assessment to the GCS motor domain [36]. In our study, most participants had no reaction of either one or both pupils. Pupillary reactivity has been identified as a strong predictor of mortality and unfavourable outcome in TBI [36]. Also, a worse prognosis for patients with fixed and dilated pupils has been reported [37]. Based on our initial data, we hypothesise that early restitution of neurological function is associated with a more favourable rehabilitation potential.

Most hospitalised participants had multiple injuries with high ISS. However, head injury was the most likely cause of death when we reviewed records of fatal cases. The value of ISS in the prediction of TBI outcome is controversial because ISS is based on anatomical rather than functional criteria, and includes injury other than TBI. This score was incorporated in one prediction model [38], whereas indirect estimates of injury severity, such as anaemia, hypotension and hypoxia, were preferred in another [39].

About one third of surgical interventions were started more than 3 hours after the accident. In patients with intracranial mass lesions, a shorter delay from loss of pupil reaction to surgery was associated with better survival [37]. Whereas patients with epidural haematoma recovered better when the delay until evacuation was short [40], the effect of this was less obvious in patients with subdural haematoma [41–43]. Therapeutic options such as early decompression of intracranial mass lesions and major cerebral oedema are preserved if delays until surgery are avoided [44].

## Conclusions

We demonstrated the feasibility of a multicentre cohort study and present initial findings on the incidence and outcome of severe TBI in Switzerland. A large population-based study is now needed to investigate potential outcome determinants and to address specific questions, such as differences in case fatality compared with other countries. Future results from the project will contribute to the evidence-base in TBI care and improve decision-making by healthcare professionals, planners, patients, and their families.

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